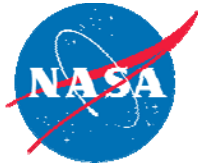


Impact of Air Injection on Jet Noise

Brenda Henderson and Tom Norum
NASA Langley Research Center

Fall Acoustics Technical Working Group
December 4 – 5, 2007
Cleveland, OH

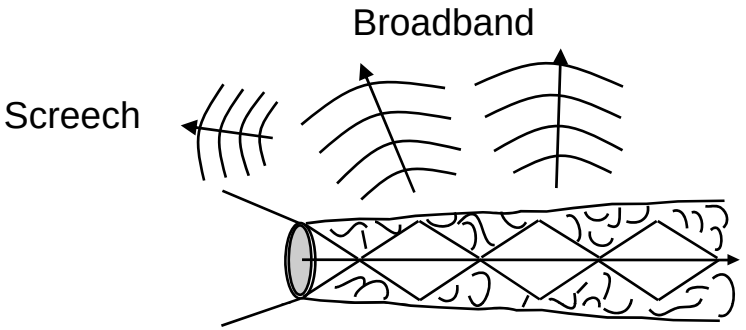
Objective

Determine impact of core fluidic chevrons on noise produced by dual stream jets

- Broadband shock noise - supersonic
- Mixing noise – subsonic and supersonic

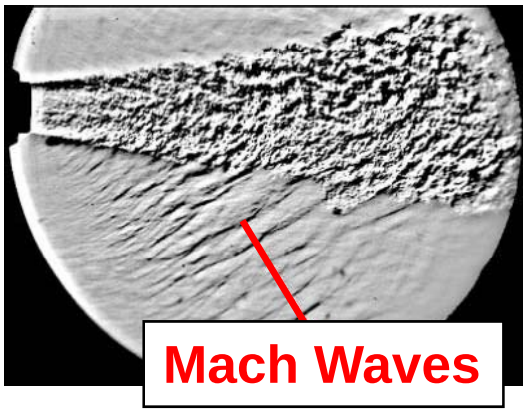
Jet Noise Sources

Shock Noise



Mixing Noise

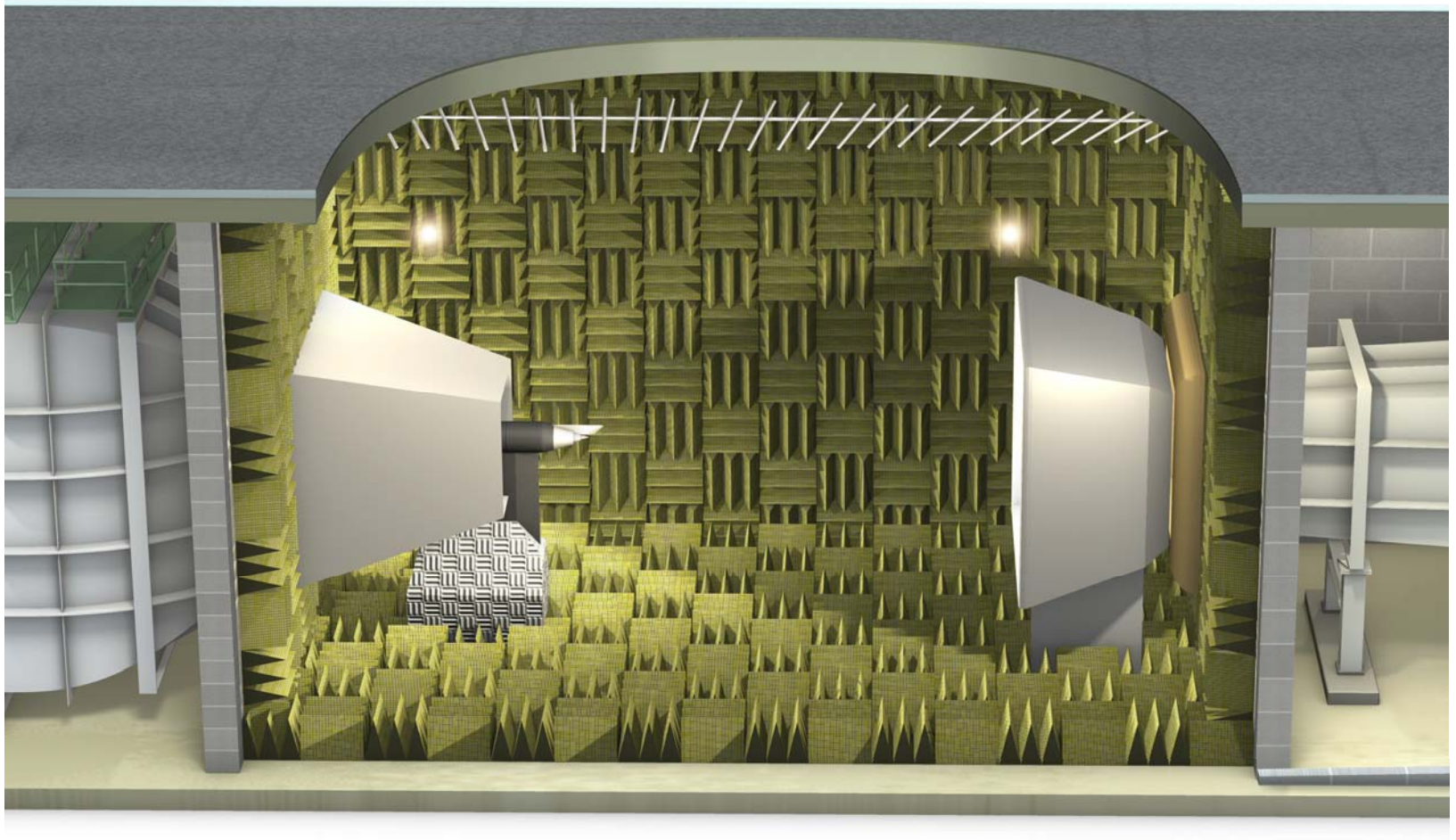
- Mixing noise
- Mach wave radiation
  - Crackle
- Shock associated noise
  - Broadband
  - Discrete
- STOVL noise/tones



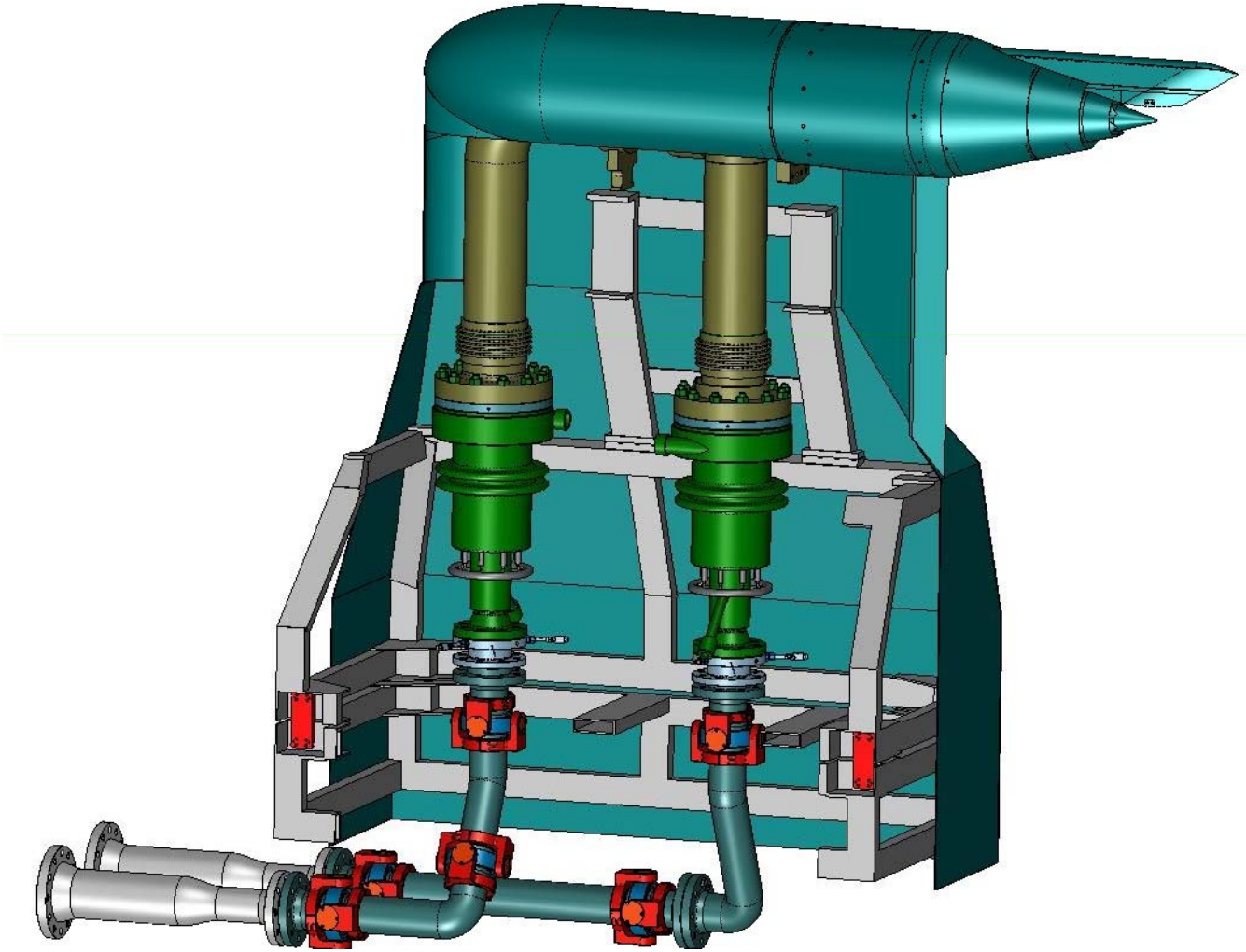
Courtesy of D. Papamoschou

NASA Langley (LSAWT)

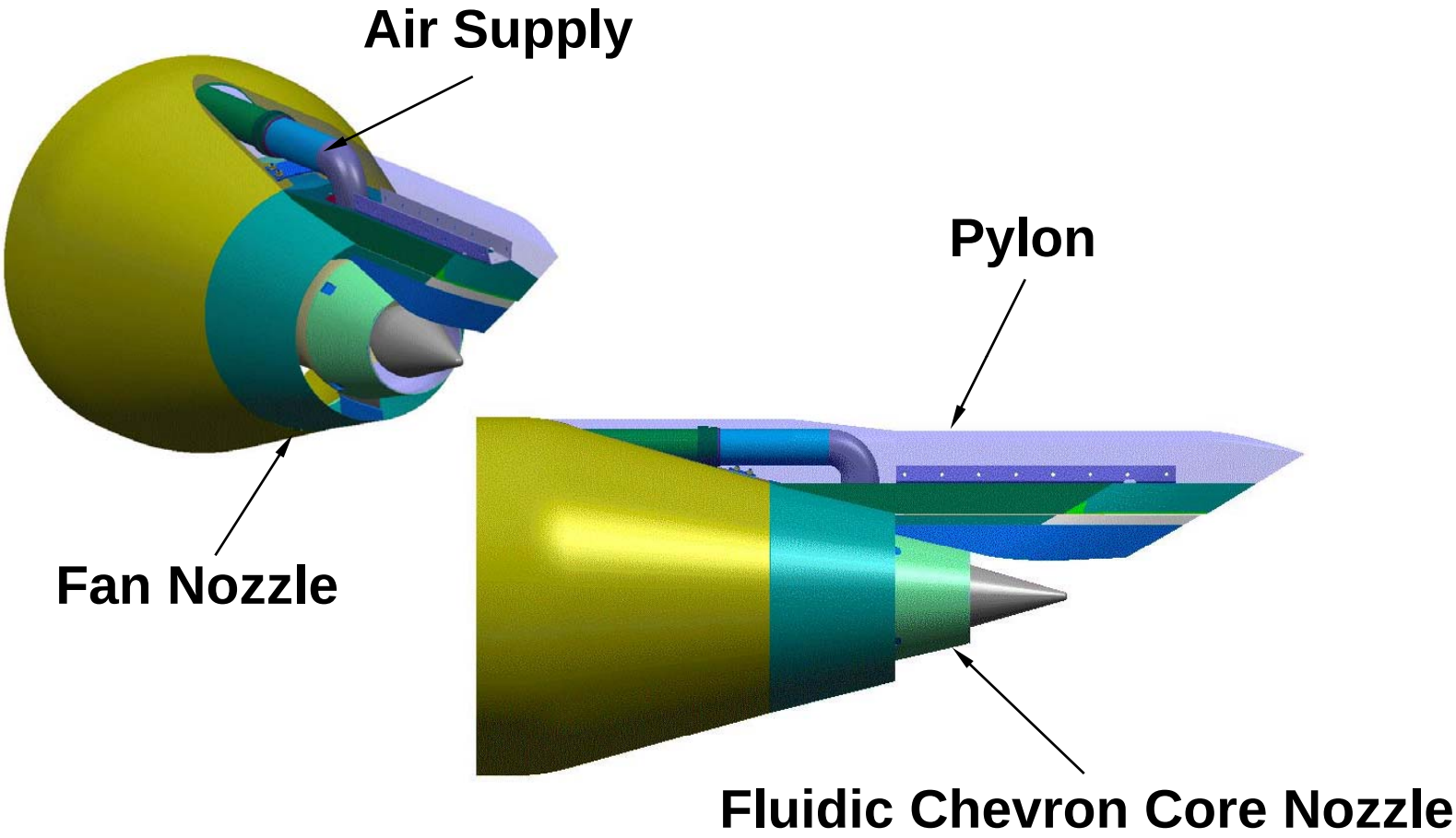
Low Speed Aeroacoustics Wind Tunnel



Jet Engine Simulator (JES)



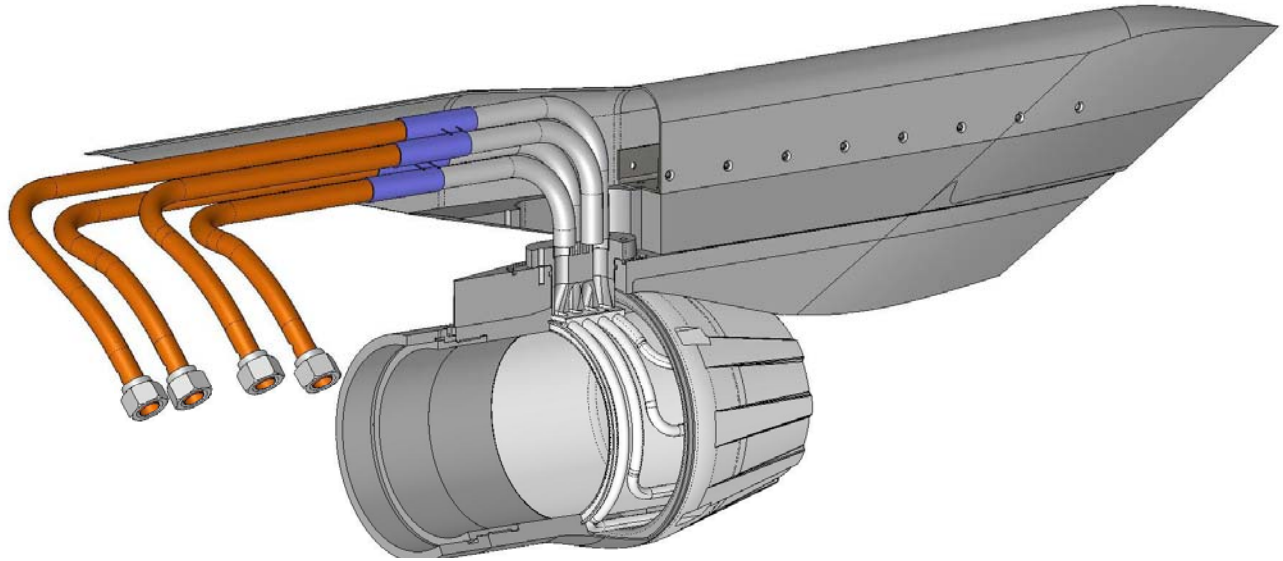
Generation II Fluidic Chevrons



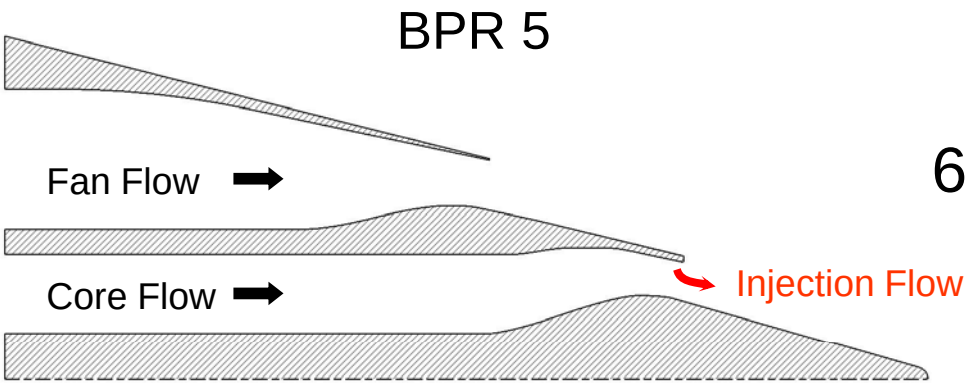
Nozzle design was the result of a partnership between NASA Langley Research Center and Goodrich Aerostructures under SAA1-561

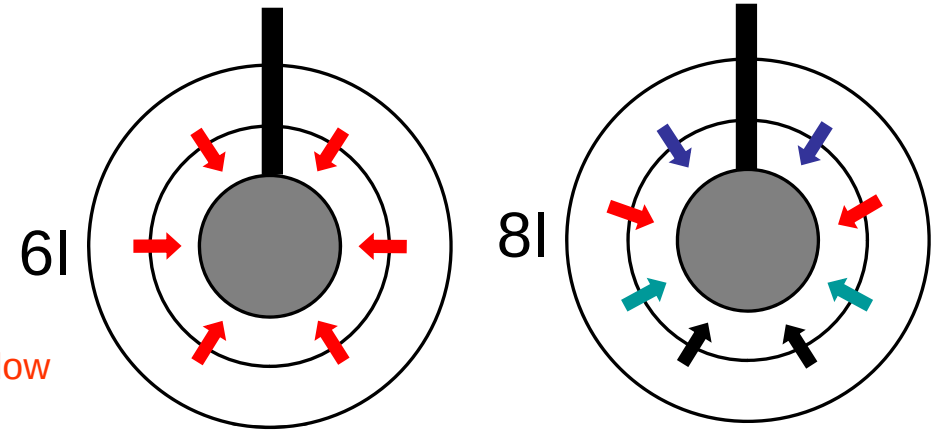
Generation III Fluidic Chevrons

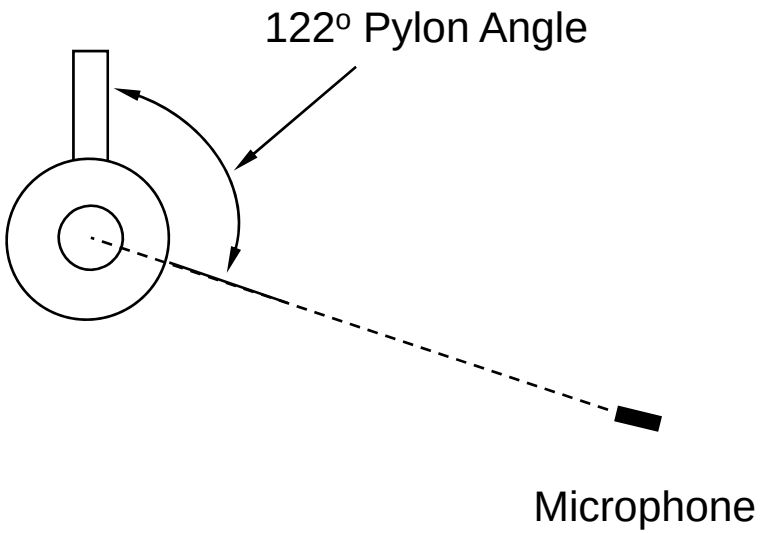
- Core fluidic chevron nozzle
- 8 injectors
  - 4 pairs independently controlled
- No common plenum



Fluidic Chevron Nozzles



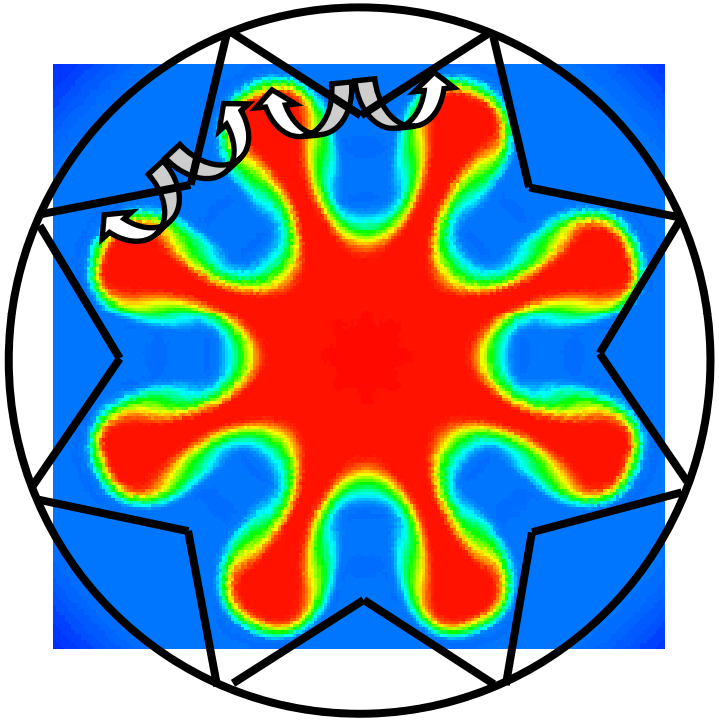


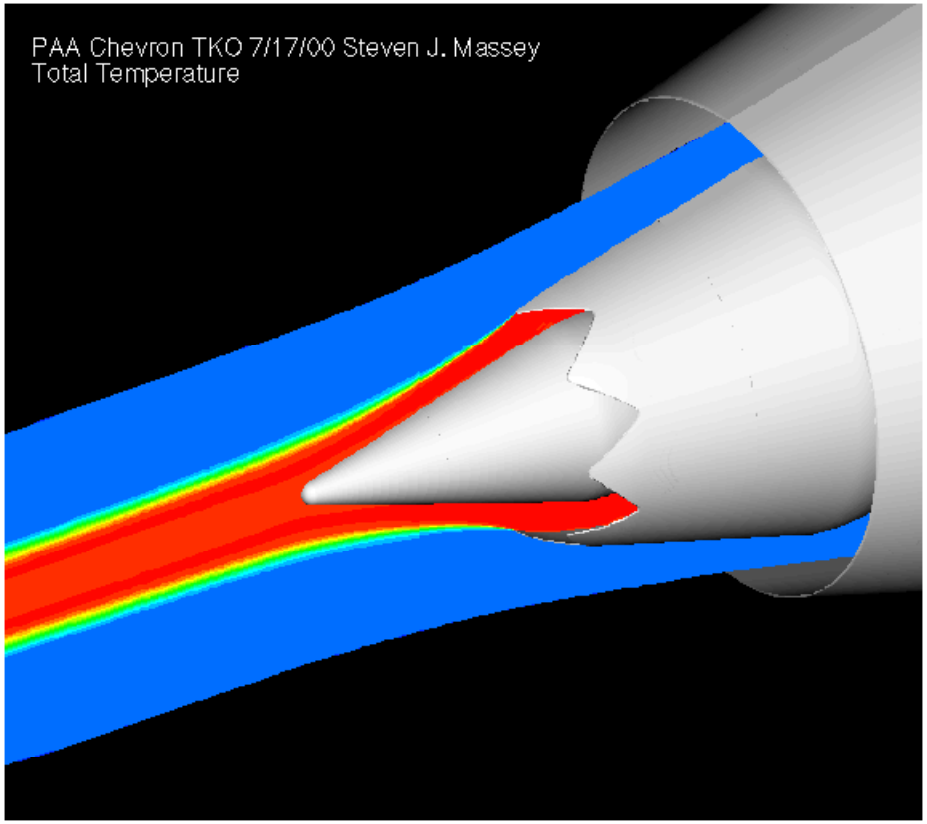


Three Air Injection Nozzles

- 6I steep injection
- 6I shallow injection
- 8I steep injection
  - azimuthal control

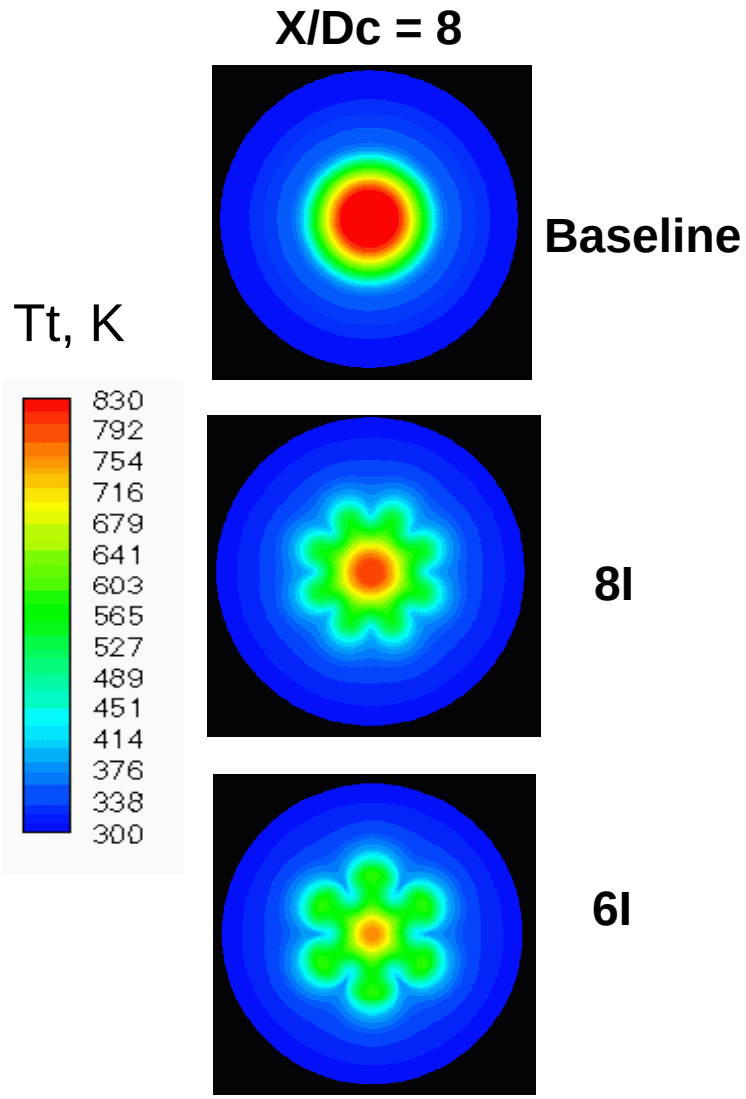
Chevron Mixing Enhancement

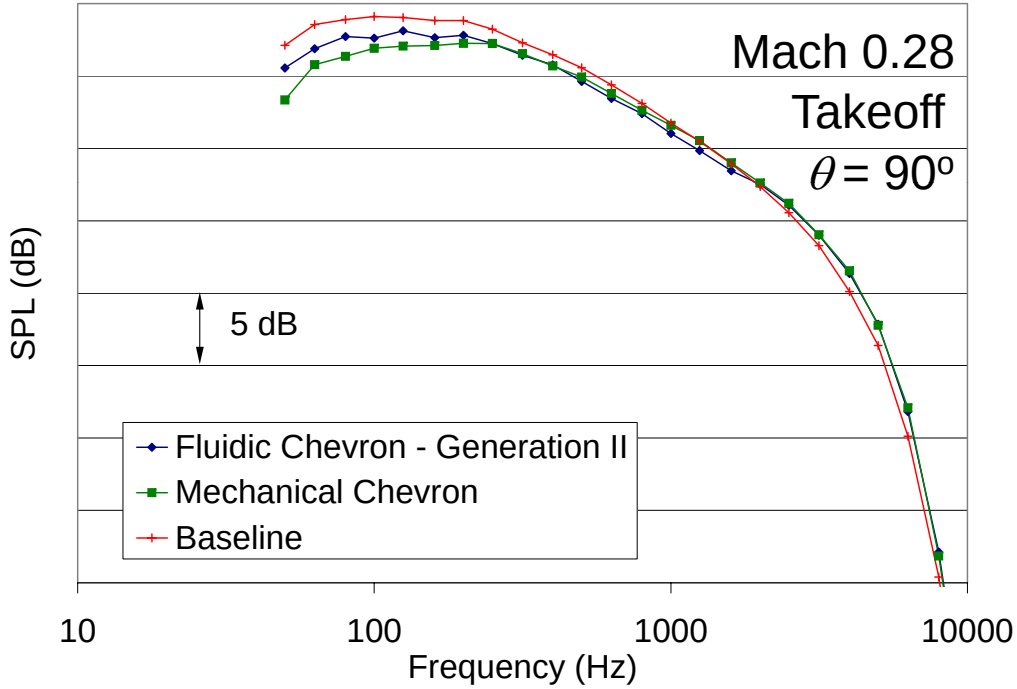




- Enhanced mixing shortens potential core and reduces volume of acoustic sources

Characteristics of Fluidic Chevrons





Experiments

NPR_c	TTR_c
1.93	1
2.04	1
2.17	1
2.30	2.5

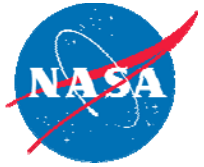
Single Stream Experiments

- Fan stream operated at tunnel conditions

NPR_c	TTR_c	NPR_f	TTR_f
1.56	**2.66**	**1.75**	**1.16**
1.61	2.13	2.23	1.05
1.82	2.13	2.23	1.05
2.04	2.39	2.23	1.05
1.61	2.26	2.35	1.17
1.82	2.26	2.35	1.17
2.04	2.39	2.35	1.17
2.17	2.46	2.35	1.17
2.04	2.39	2.45	1.04
2.17	2.46	2.5	1.05

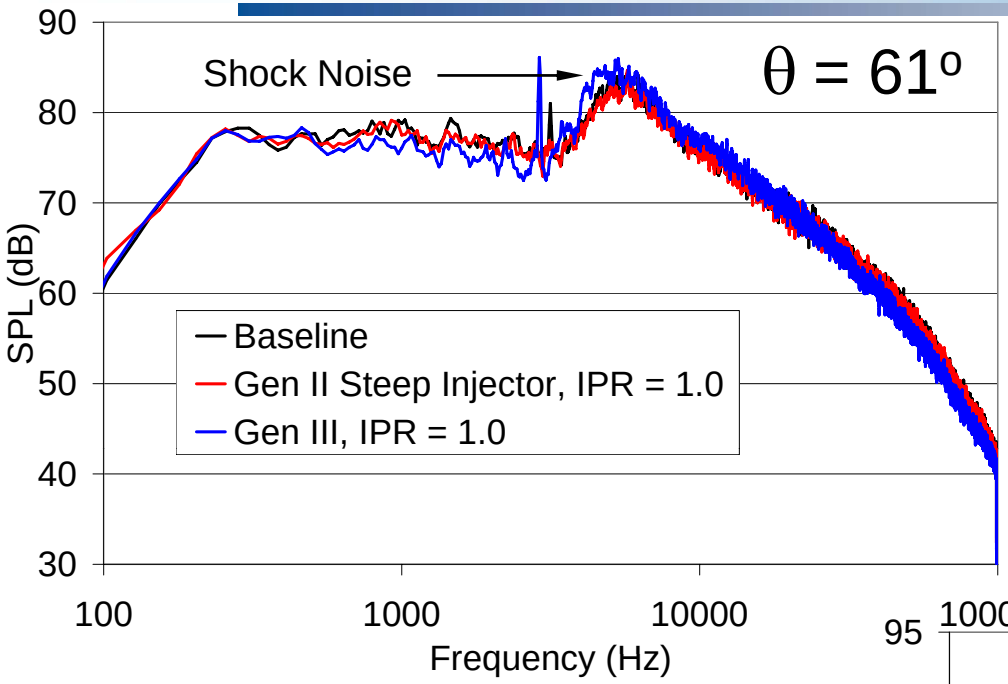
Dual Stream Experiments

Free-stream Mach number = 0.10



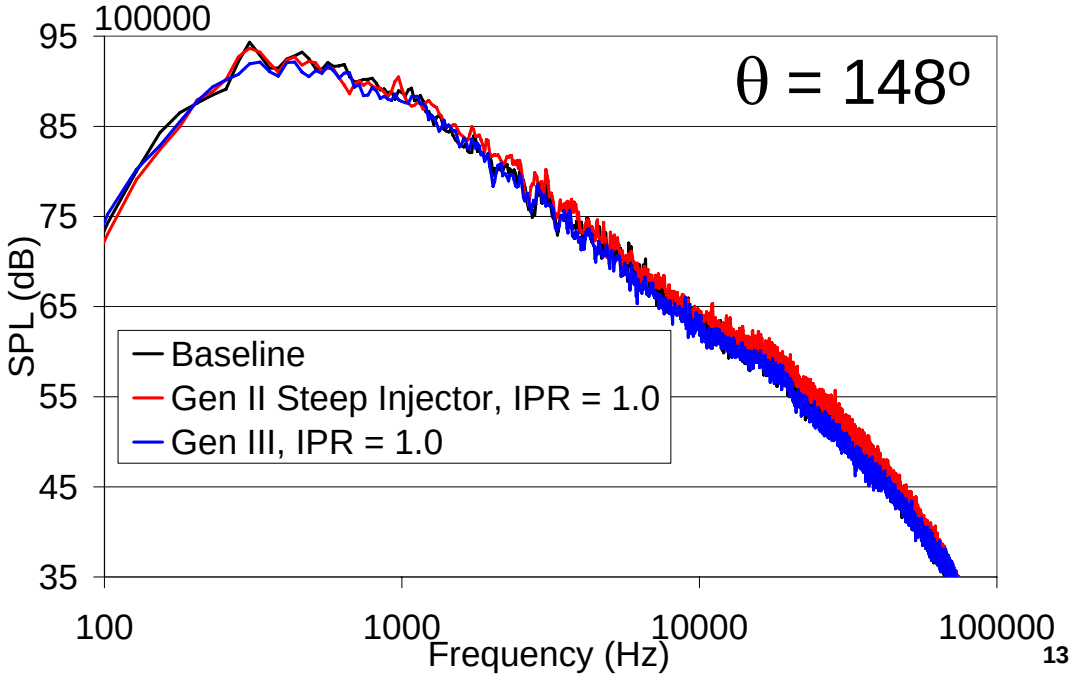
Single Stream Results

Baseline

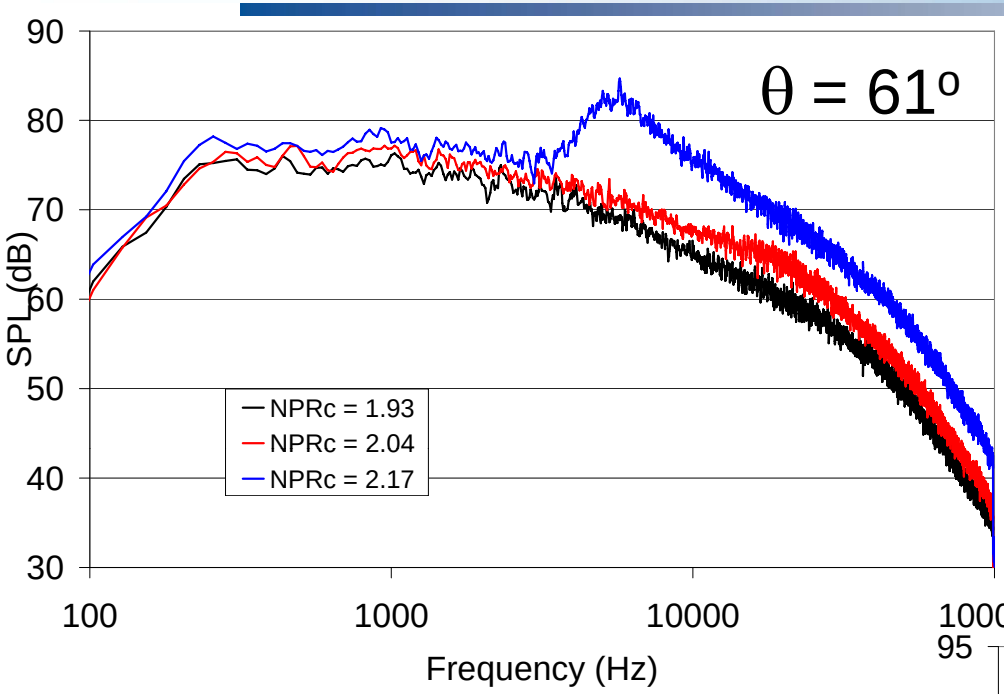


Baseline nozzle and injection nozzles with IPR = 1.0 have similar noise characteristics

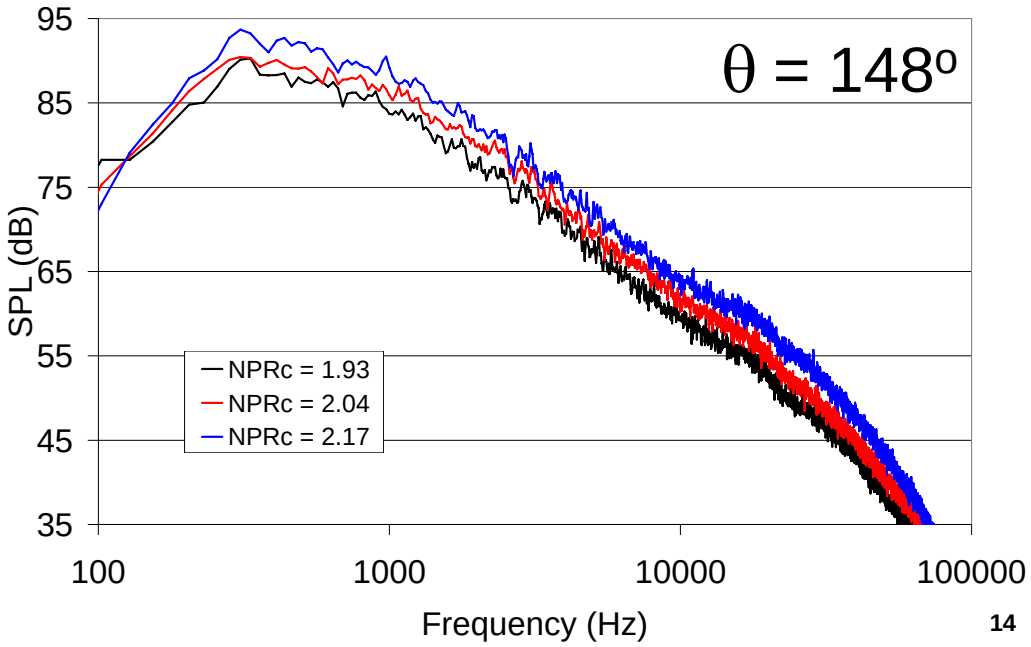
$NPR_c = 2.17$



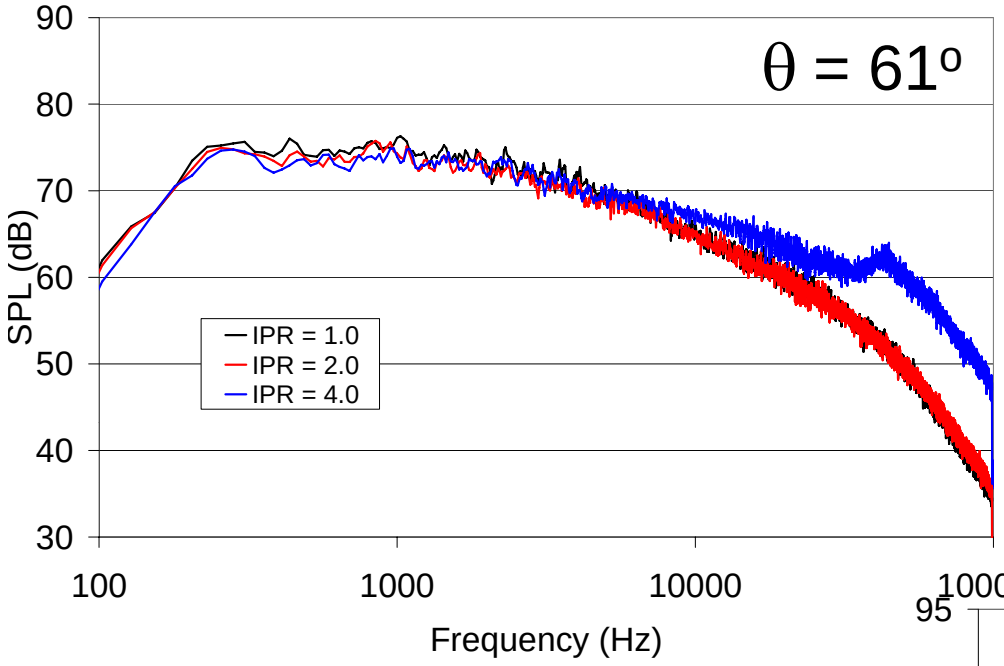
Effect of Increasing NPR_c



Well defined shock noise peak at $NPR_c = 2.17$

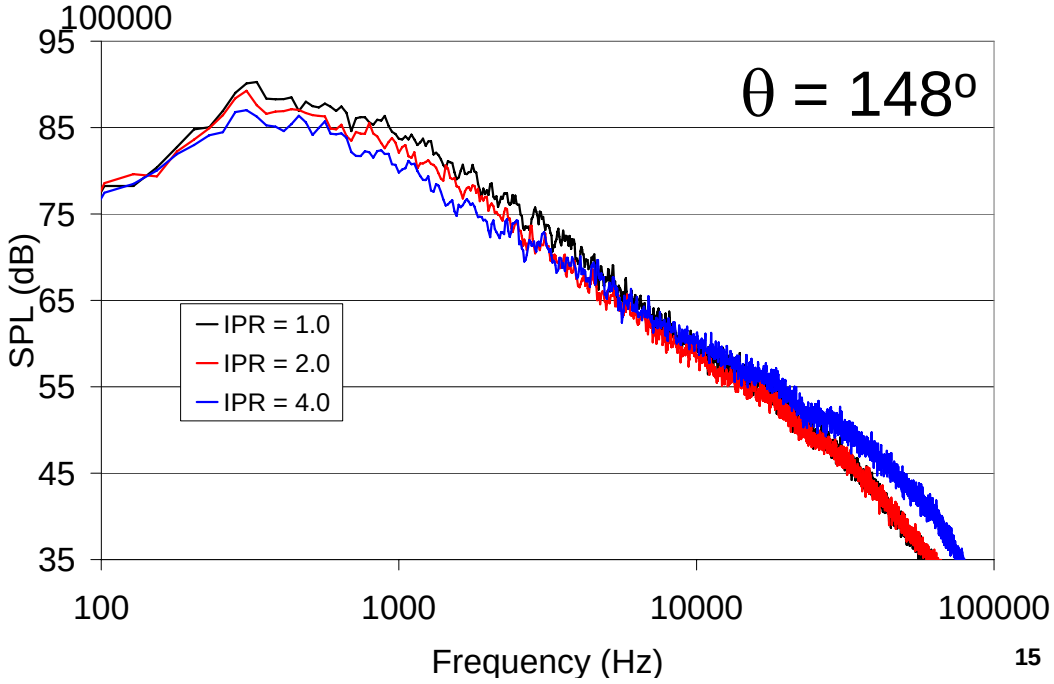


Injection at Low Supersonic Speeds

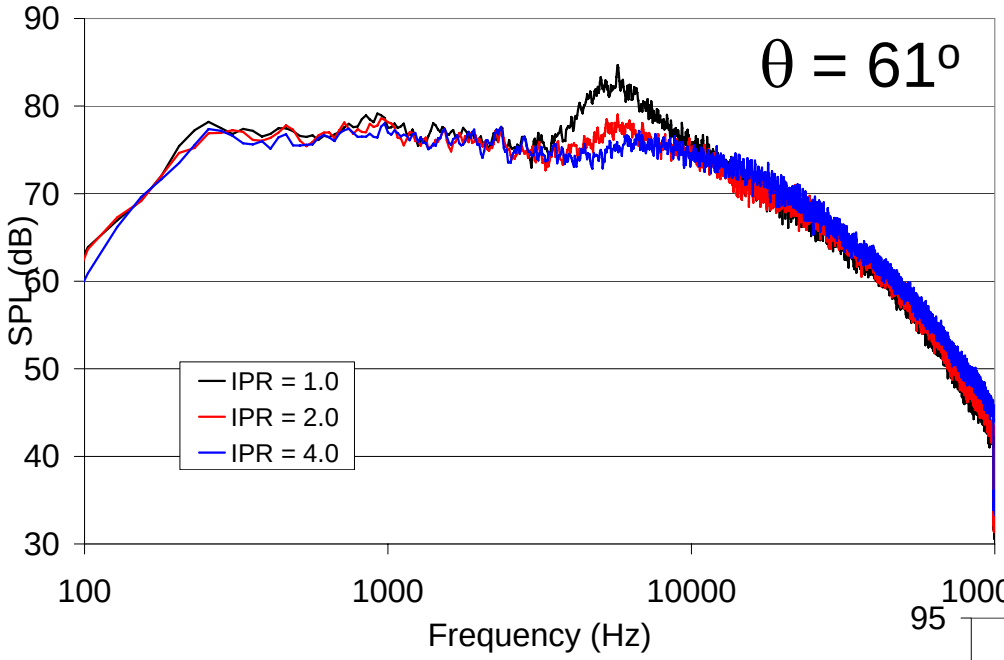


- Injector noise is is not suppressed
- Increases in IPR produce reductions in mixing noise near peak jet noise angle

$NPR_c = 1.93$

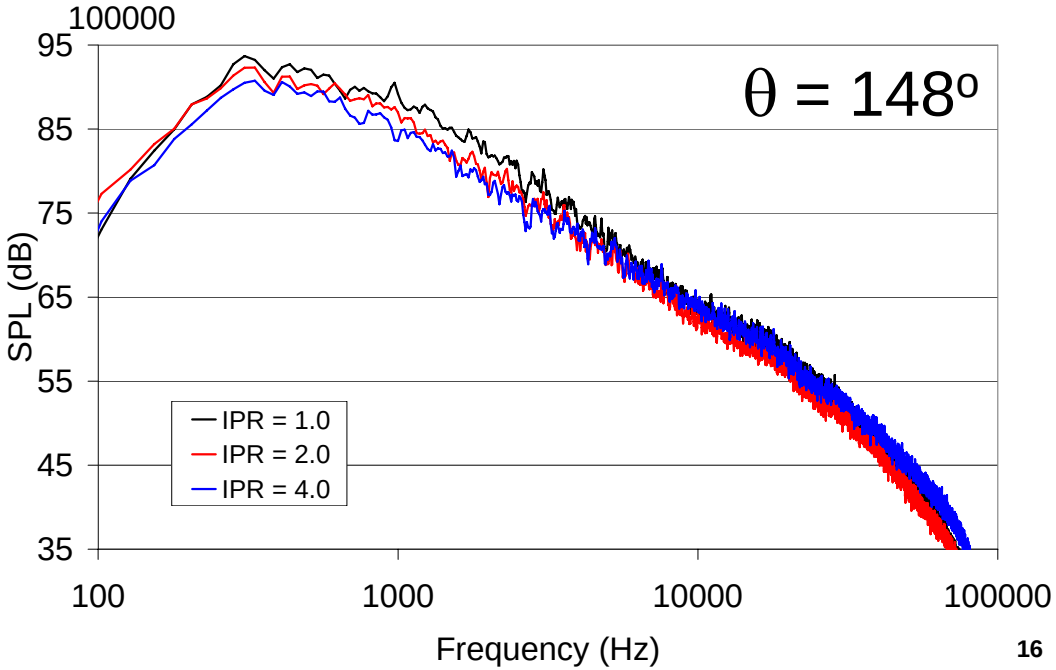


Injection for Well-Defined Shock Noise

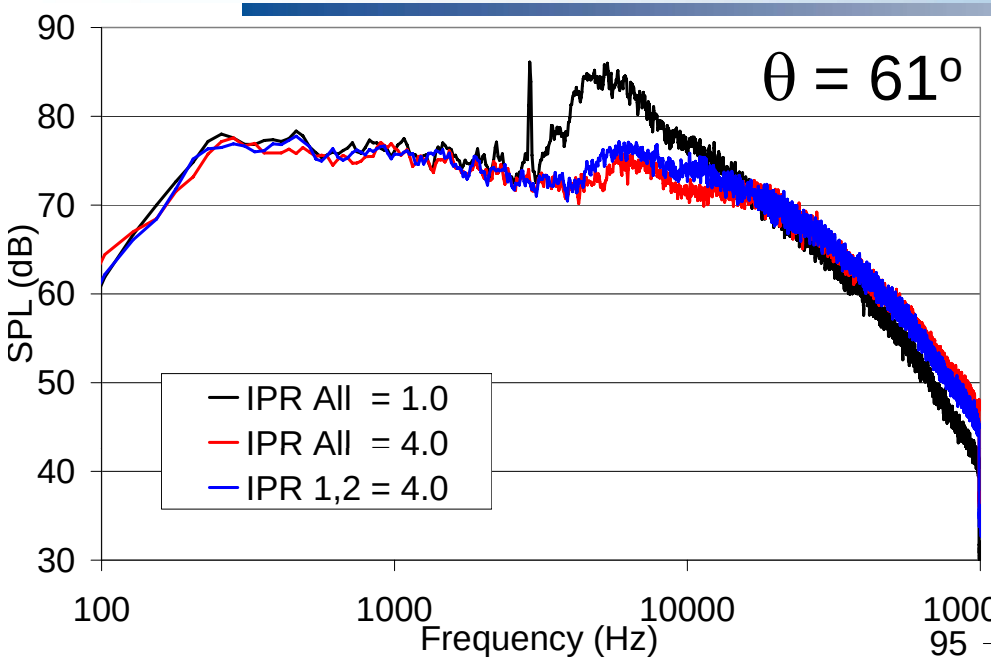


Increases in IPR produce reductions in shock noise and mixing noise

$NPR_c = 2.17$



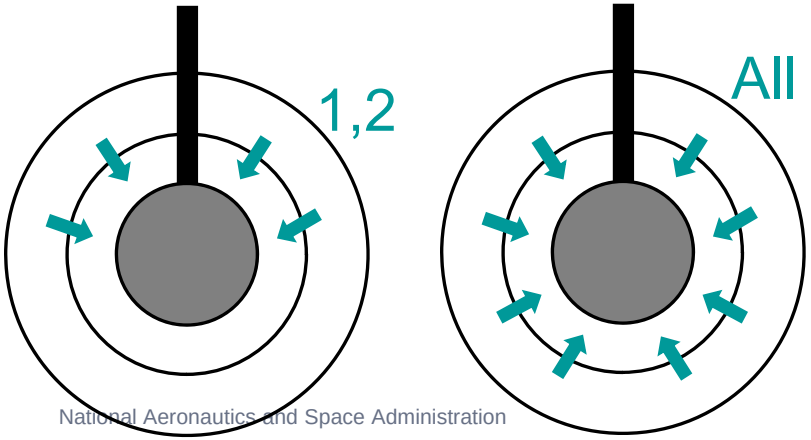
Azimuthal Control for Shock Noise

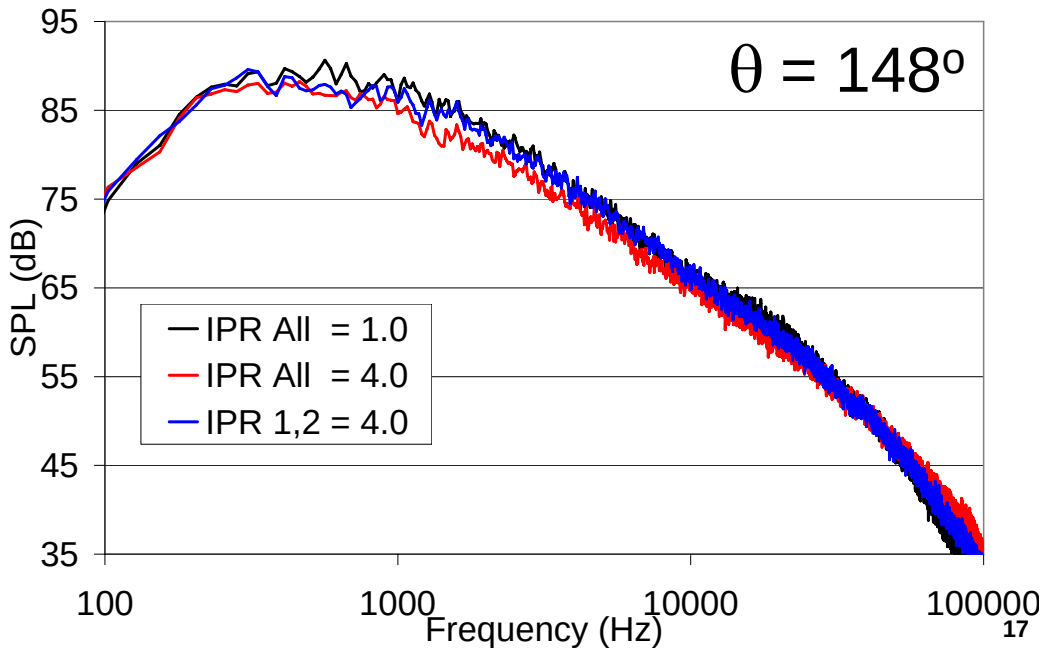


Significant shock noise reduction can be achieved with injection near pylon

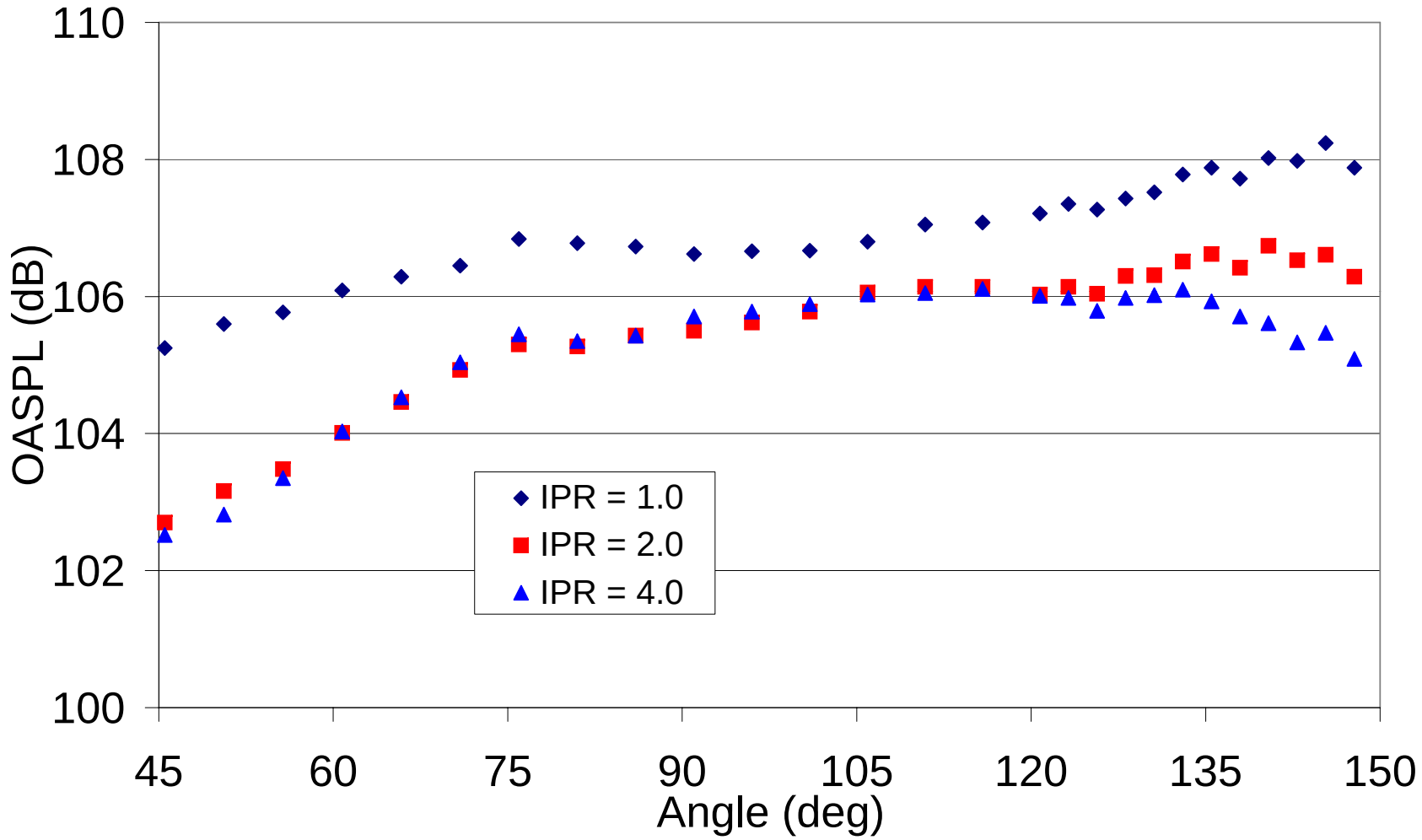
$$\frac{\dot{m}_{injection_{1,2}}}{\dot{m}_{core}} = 1.1\%$$

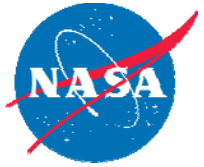
$NPR_c = 2.17$





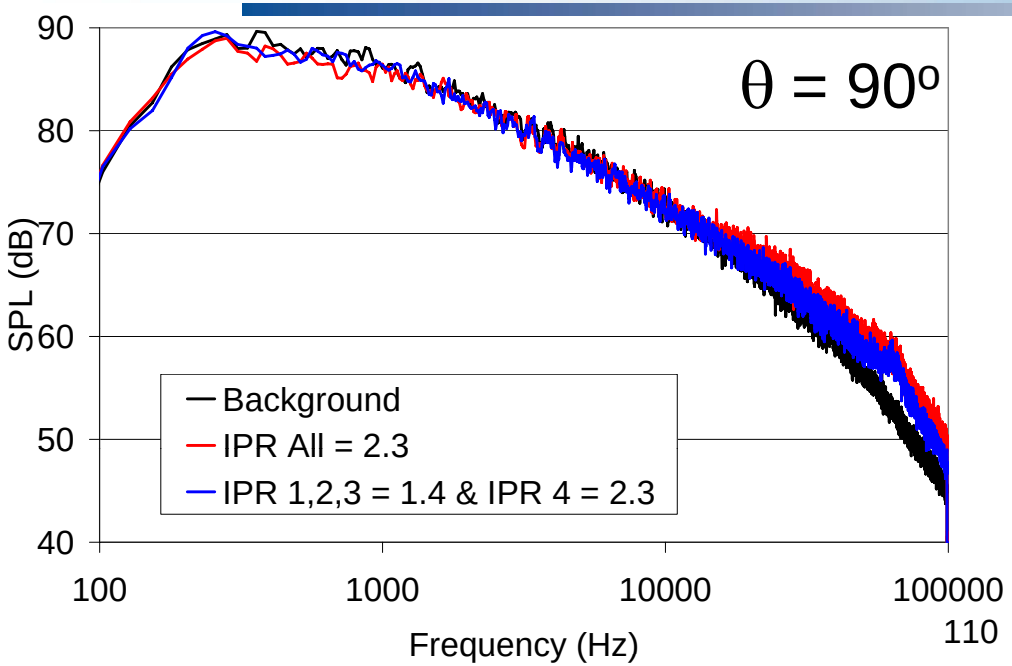
Impact of Injection on Sideline Directivity





Dual Stream Results

Injection at Subsonic Core and Fan Speeds

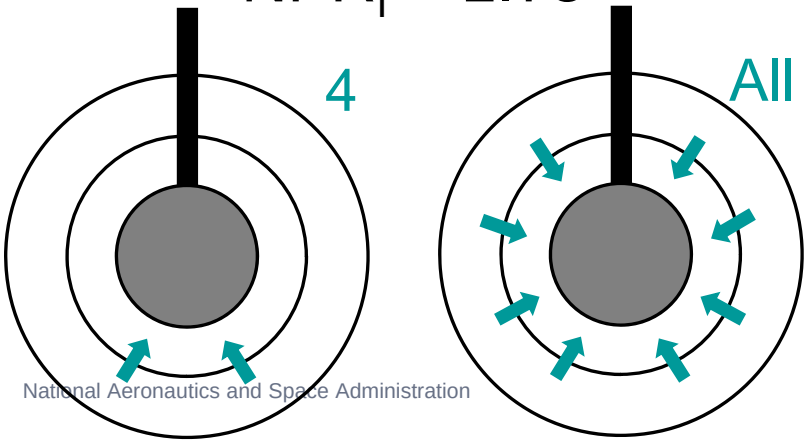


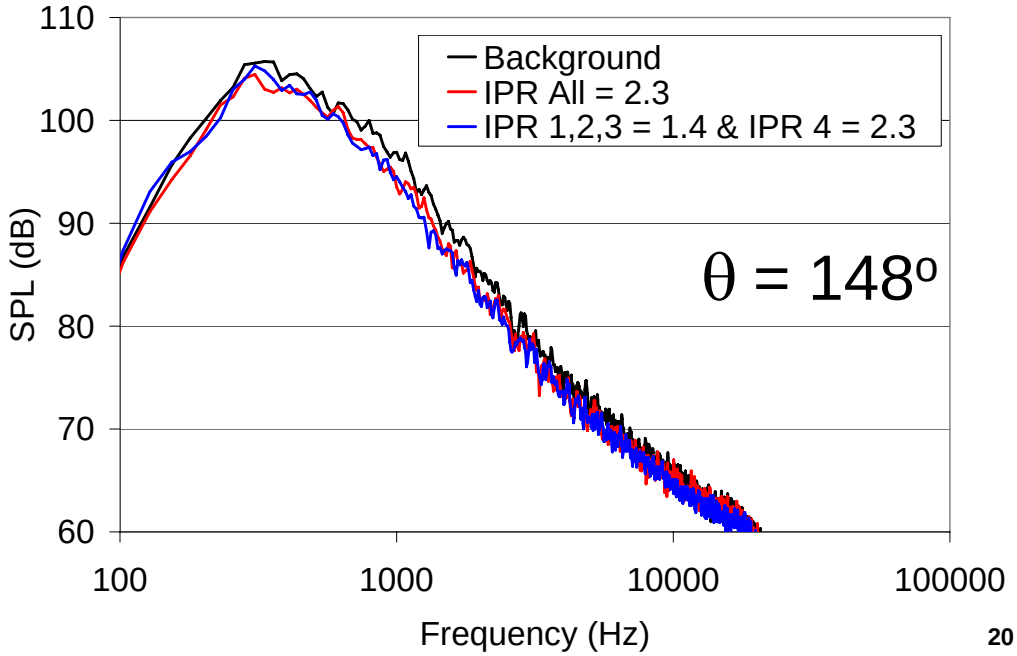
Mixing noise reduction can be achieved with injection near observation side of jet

$$\frac{\dot{m}_{injection_{1,2}}}{\dot{m}_{core}} = 1.6\%$$

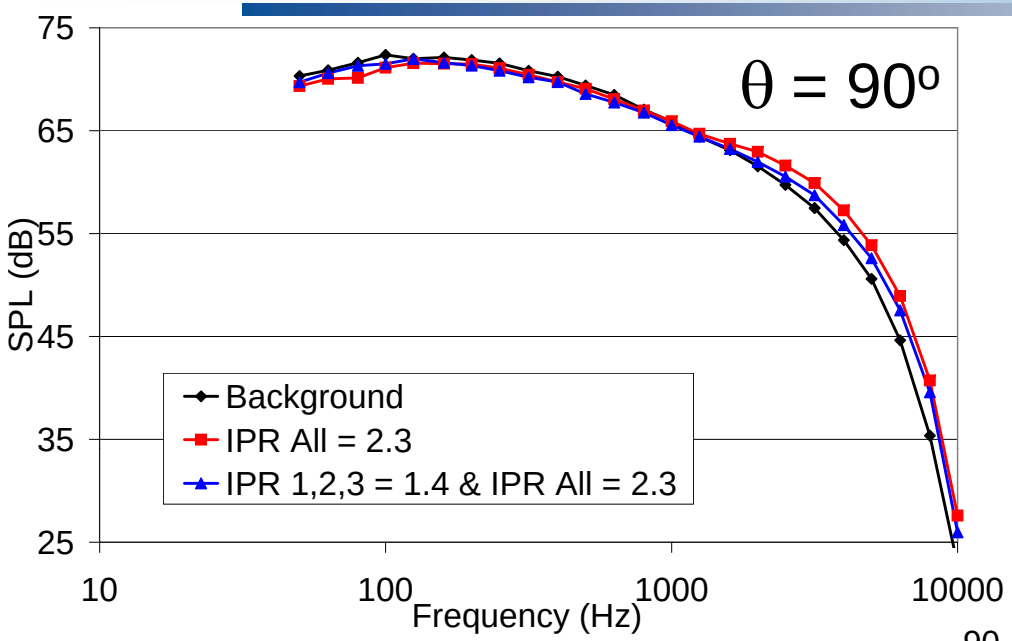
$NPR_c = 1.56$

$NPR_f = 1.75$





Injection at Subsonic Core and Fan Speeds

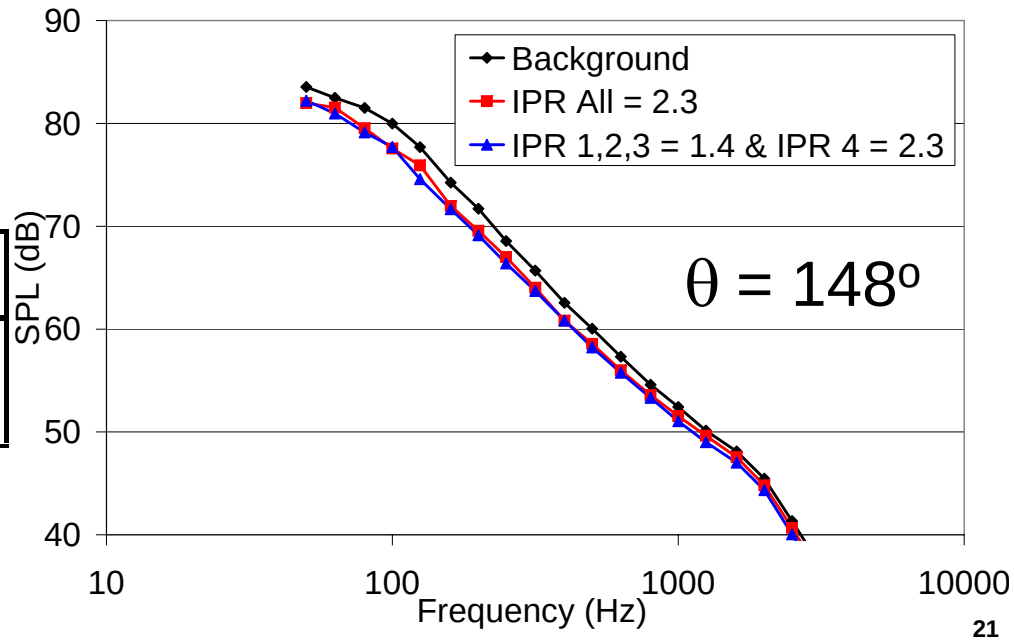


Injection produces mixing noise reduction at peak jet noise angle with slight increase in high frequency noise at 90º

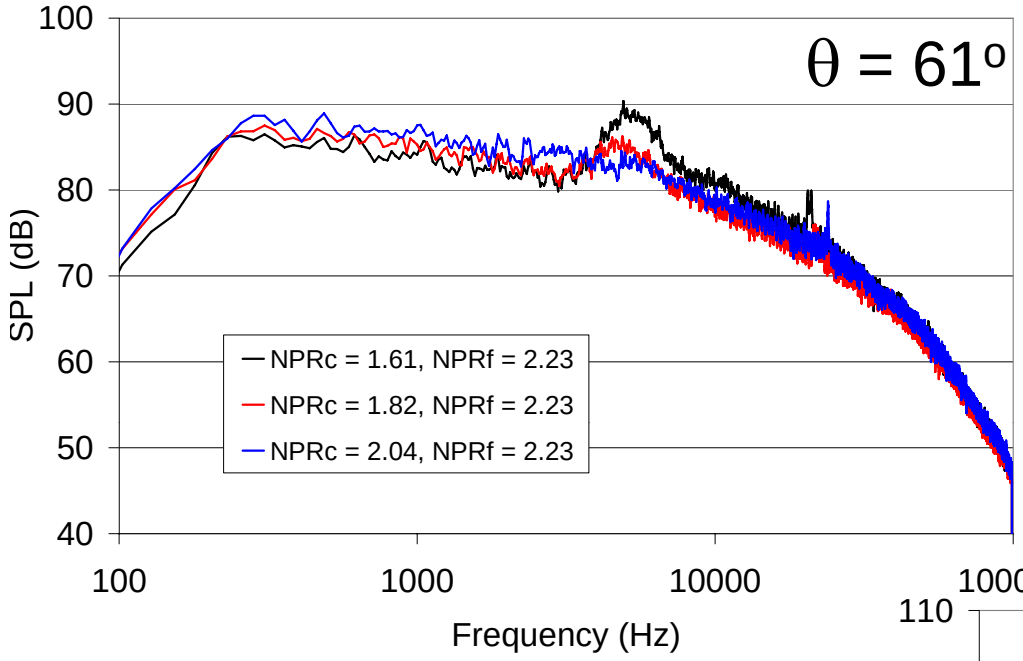
$NPR_c = 1.56$

$NPR_f = 1.75$

Nozzle	IPR	EPNL (EPNdB)	Injection Mass (% Core)
Baseline		90.4	
Air Injection	All = 2.3	89.6	2.9
Air Injection	1,2,3 = 1.4 & 4 = 2.3	89.4	1.6

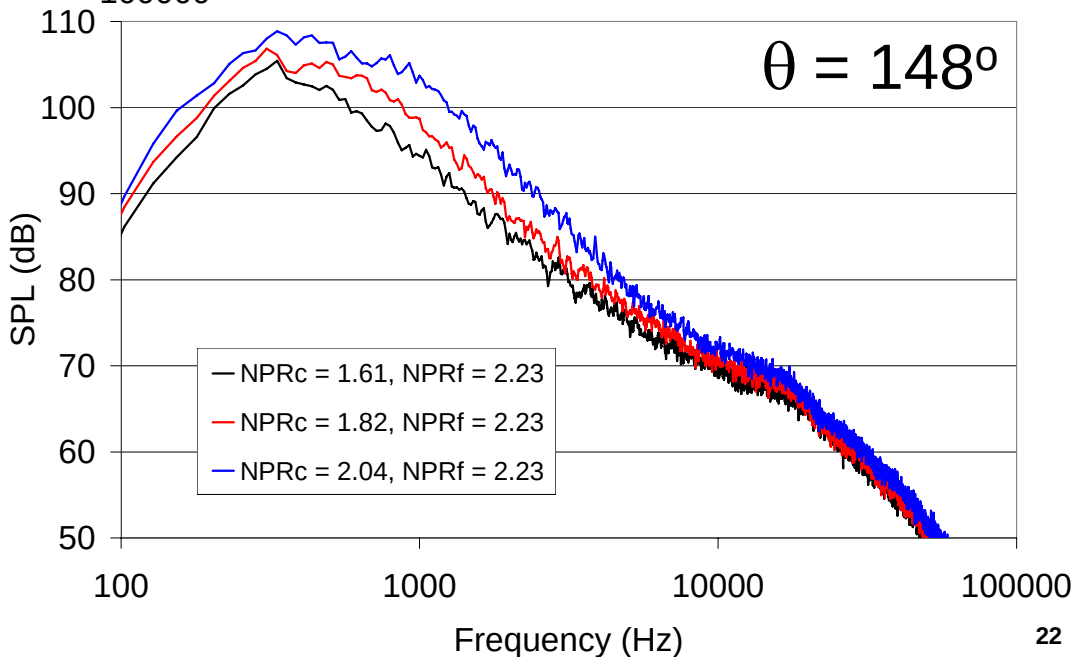


Baseline Results at $NPR_f = 2.23$

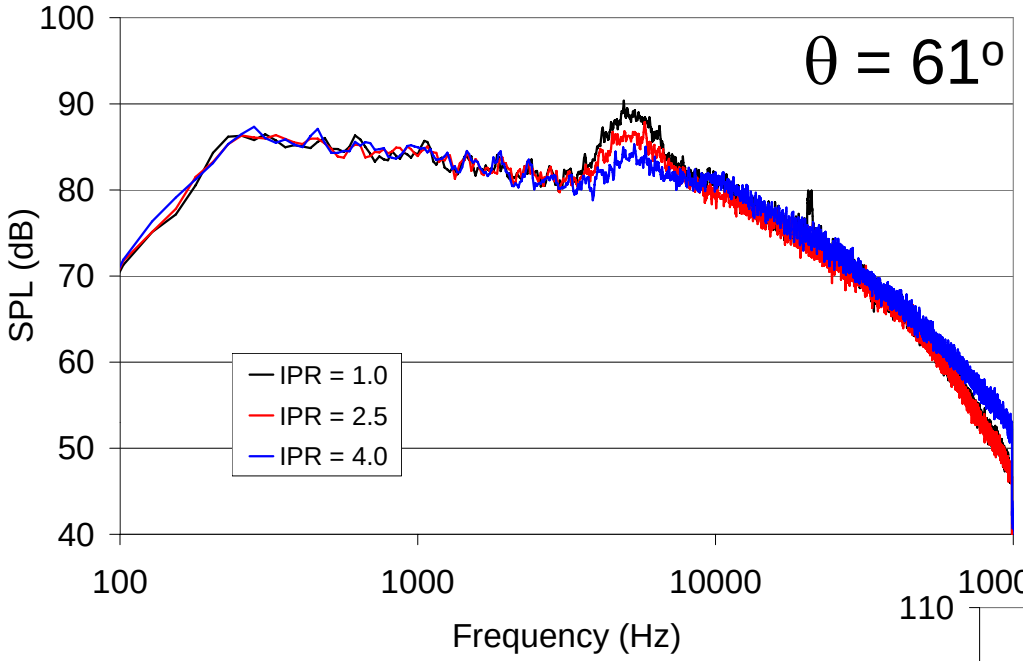


Increasing NPR_c

- Decreases shock noise peak
- Increases mixing noise near peak jet noise angle



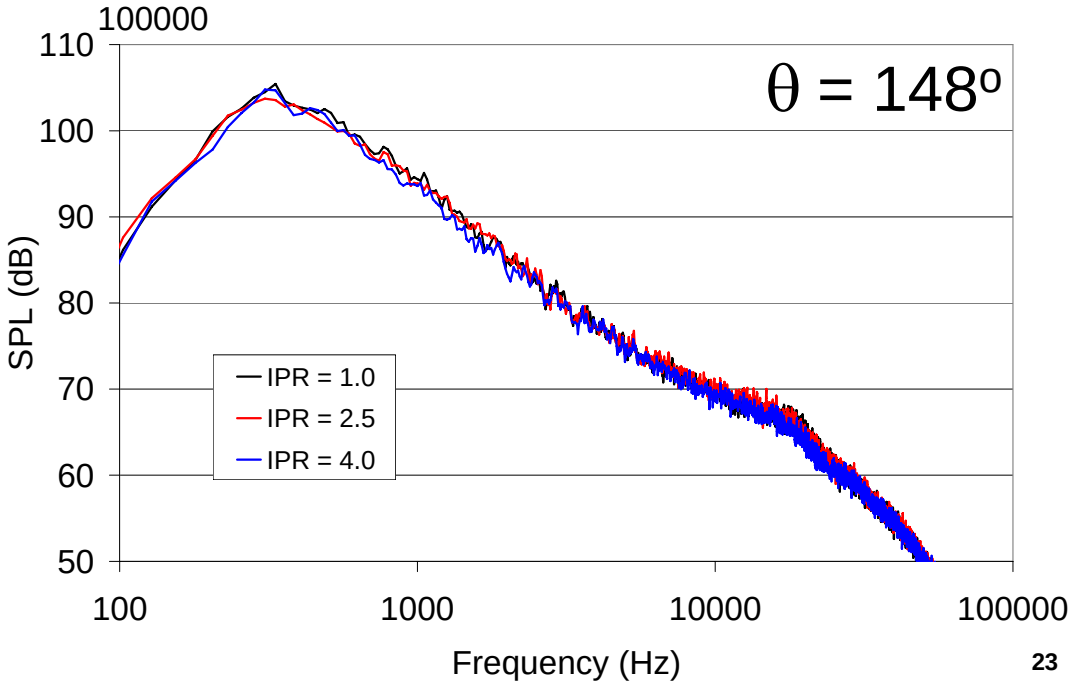
Injection at Subsonic Core Speeds



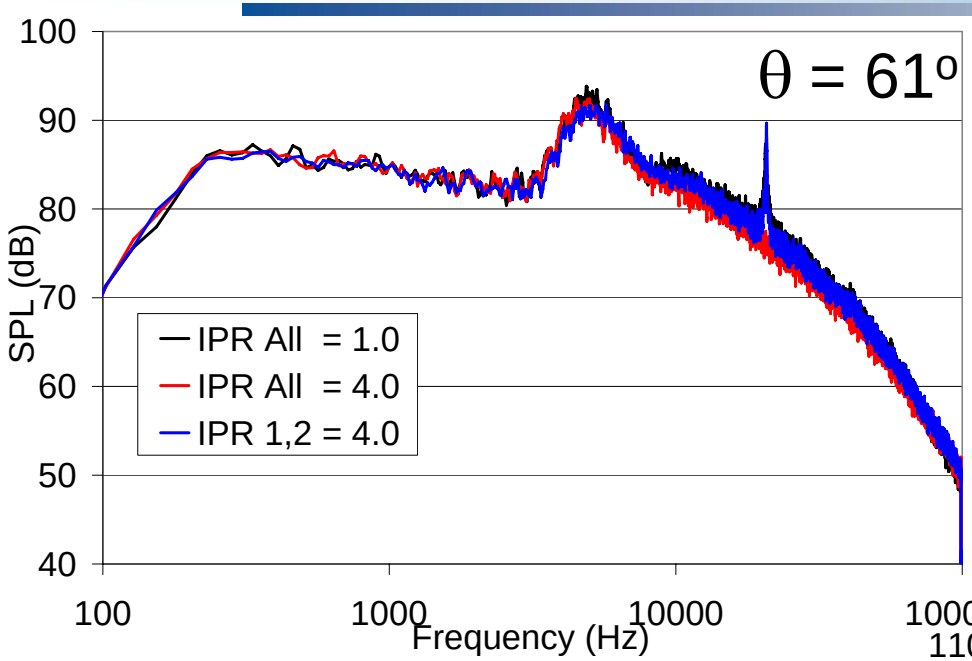
Increasing IPR decreases shock peak

$NPR_c = 1.61$

$NPR_f = 2.23$



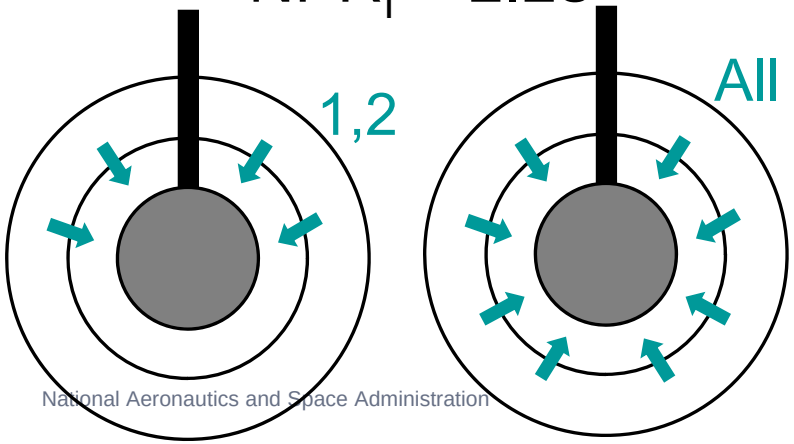
Azimuthal Control at Subsonic Core Speeds

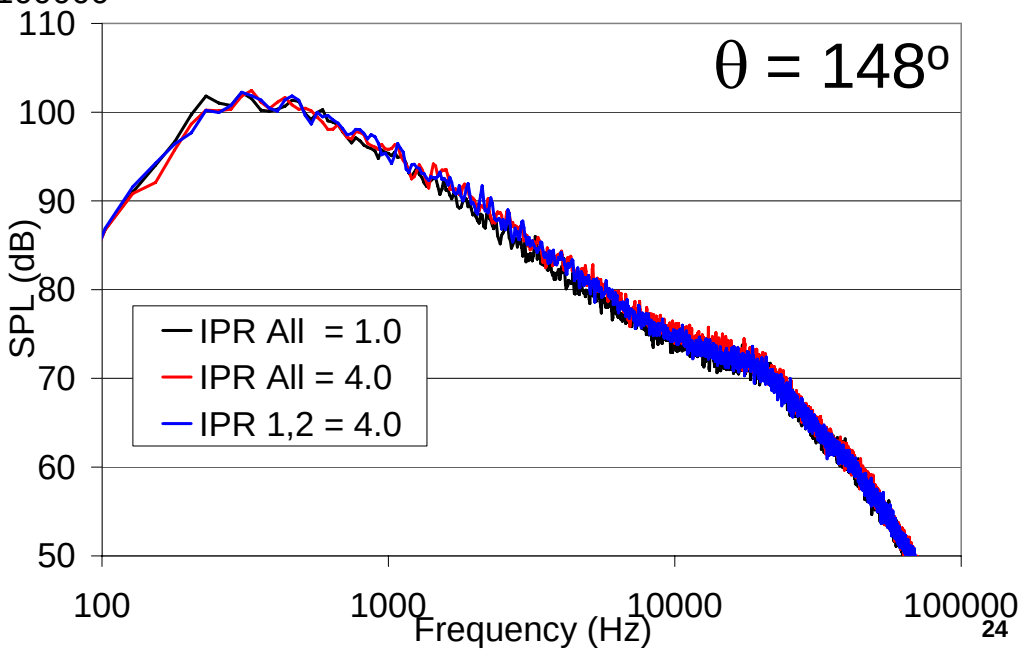


No noise reduction with Gen III nozzle due to low mass flow rates or steeper injectors

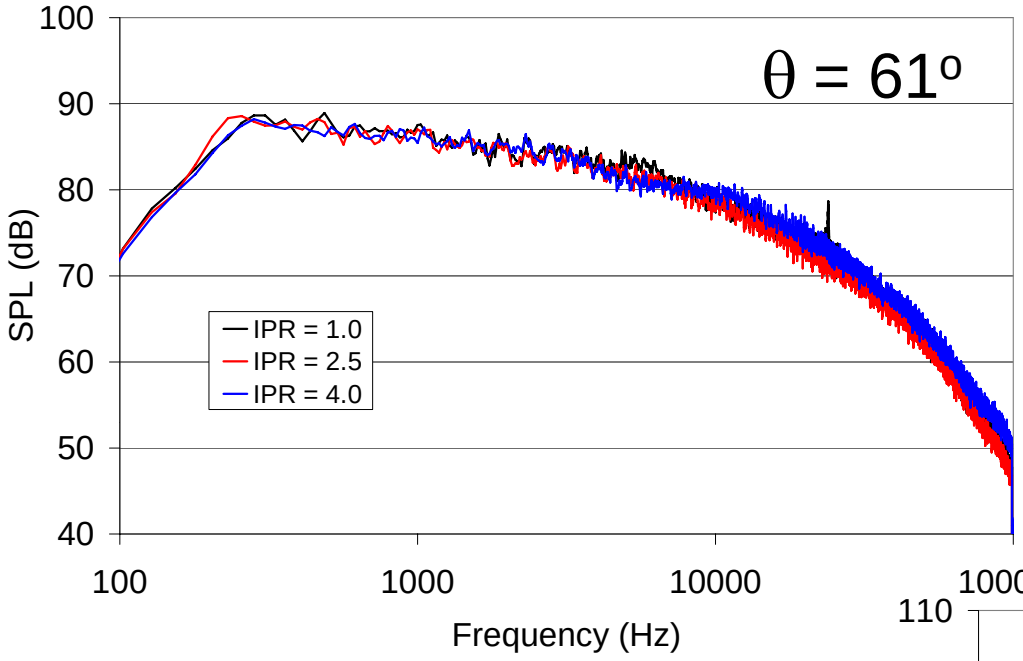
$NPR_c = 1.61$

$NPR_f = 2.23$





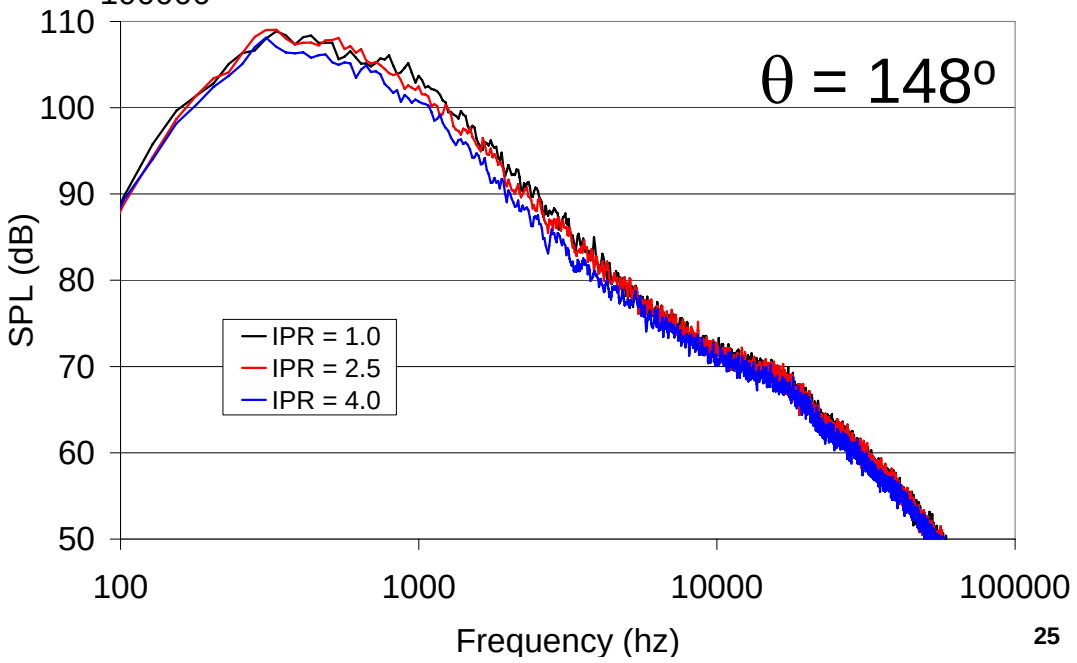
Injection at Supersonic Core Speeds



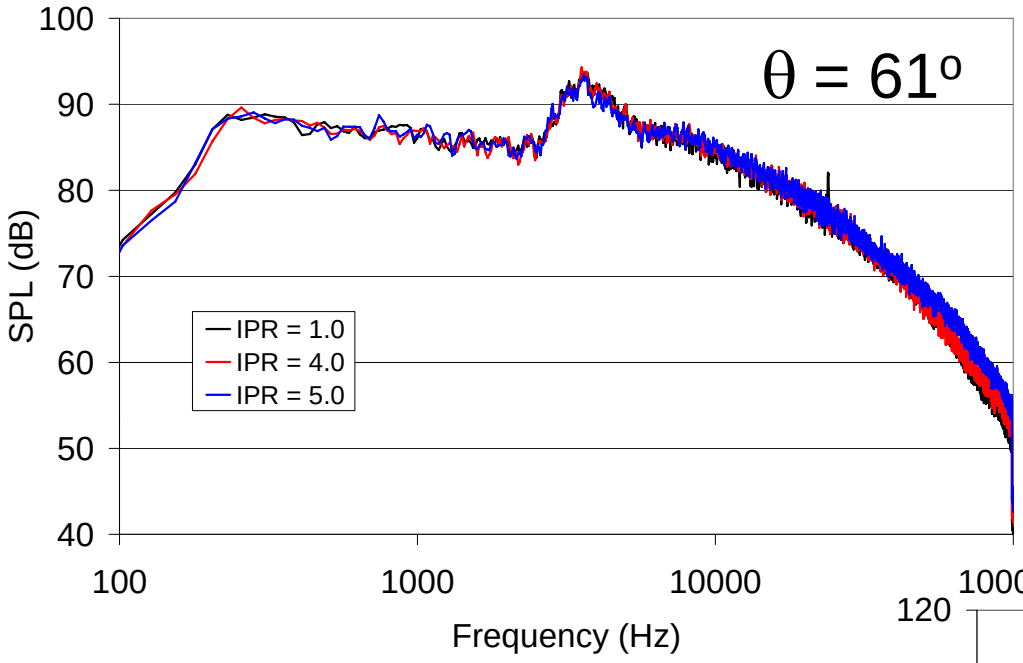
Increases in IPR produce reductions in noise near peak jet noise angle

$NPR_c = 2.04$

$NPR_f = 2.23$



Injection at Subsonic Core Speeds

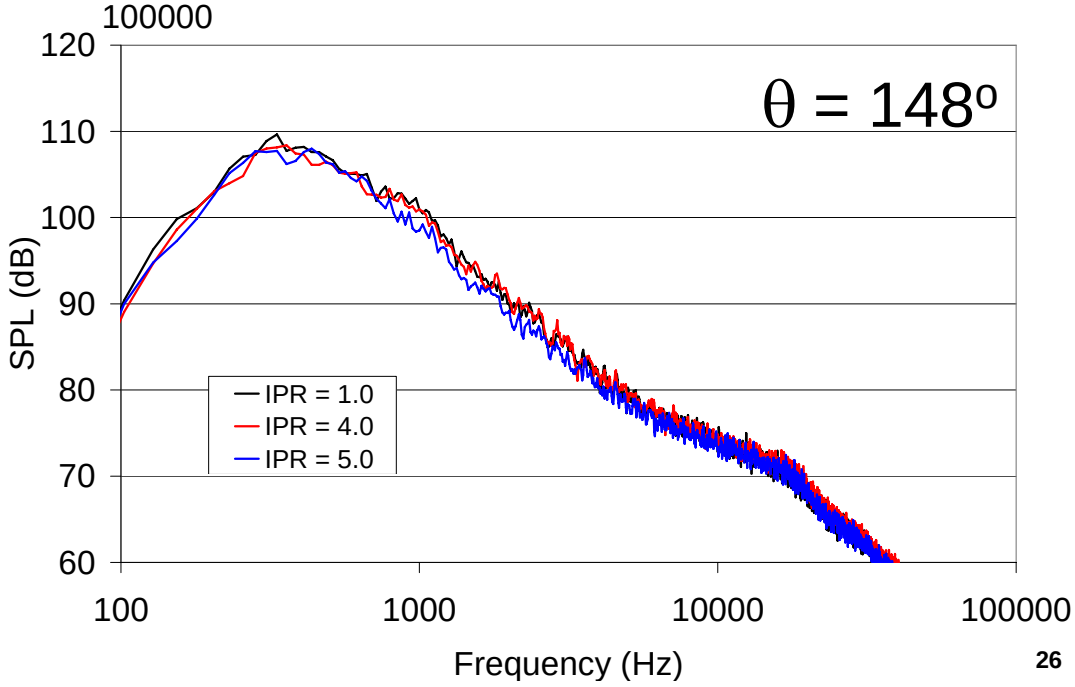


Increasing IPR

- Has no impact on broadband shock noise
- Slightly reduces noise at peak jet noise angle

$NPR_c = 1.82$

$NPR_f = 2.35$



Points of Discussion

- Injection impacts shock structure and stream disturbances through enhanced mixing
  - May impact constructive interference between acoustic sources
- High fan pressures may inhibit mixing produced by core injectors
  - Fan stream injection may be required for better noise reduction

Future Plans

- Modification of Gen II nozzles to allow for some azimuthal control
  - Will allow for higher mass flow rates
  - Will allow for shallower injection angles
- Flow field study – spring, 2008
- CFD analysis of flow

Conclusions

- Injection can reduce well-defined shock noise
- Injection reduces mixing noise near peak jet noise angle